IKONOS DEM EVALUATION

Eric Constance

USGS

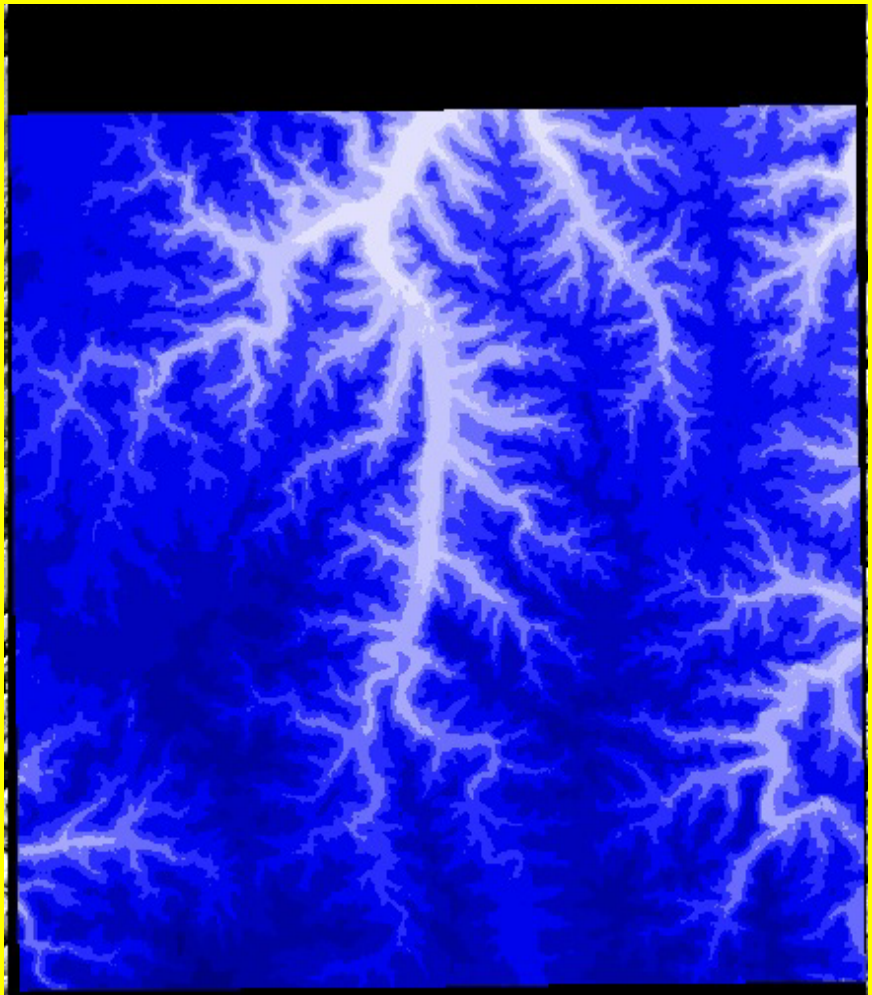
March 25, 2002

IKONOS DEM

Partial quad coverage

Acquired Nov, 2001

Leaf-off



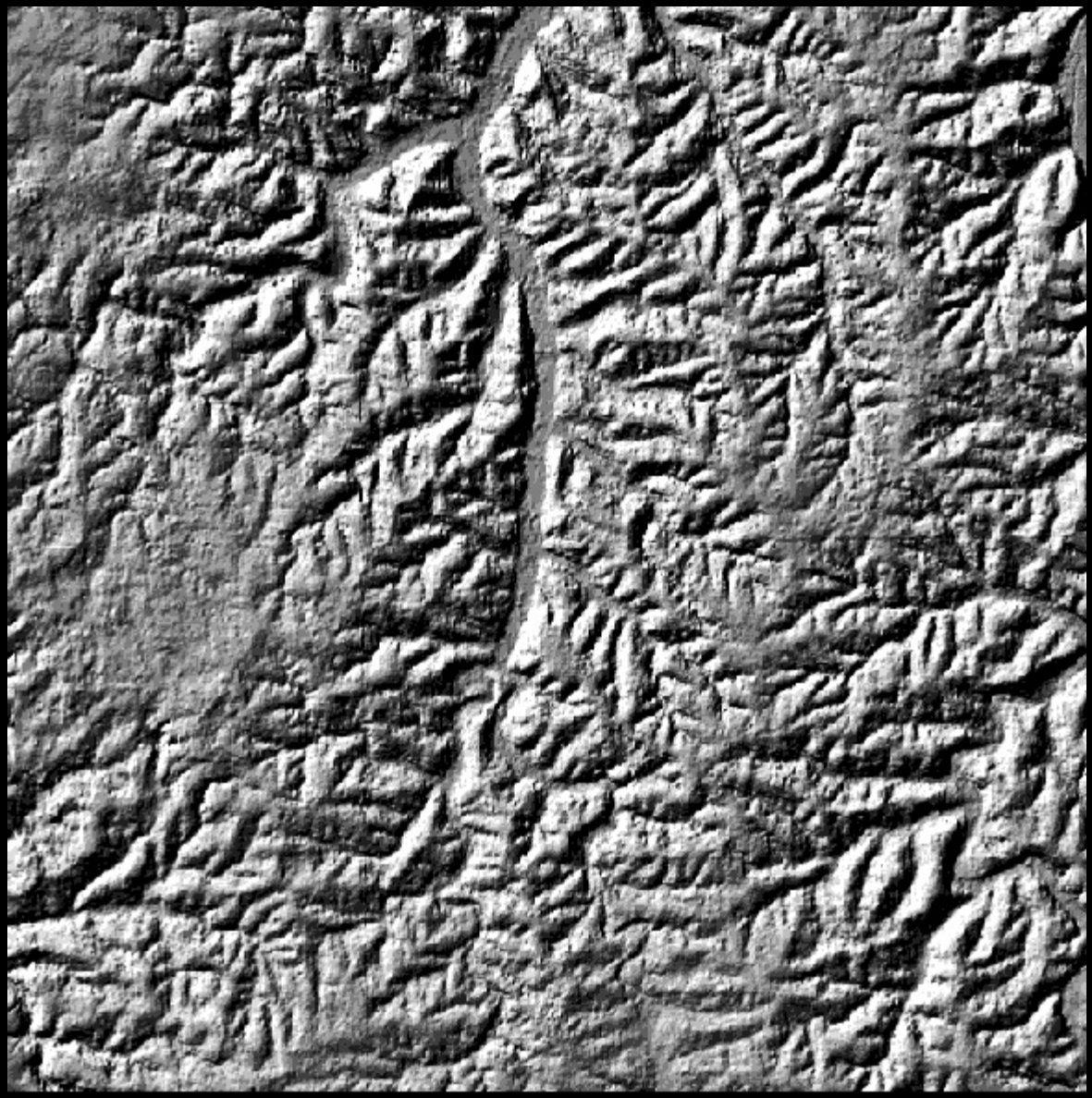
Kaintuck Hollow, MO Quadrangle

IKONOS DEM – Shaded Relief

IKONOS

0.5 arc-second spacing (about 15 meters)

Produced from IKONOS stereo pair

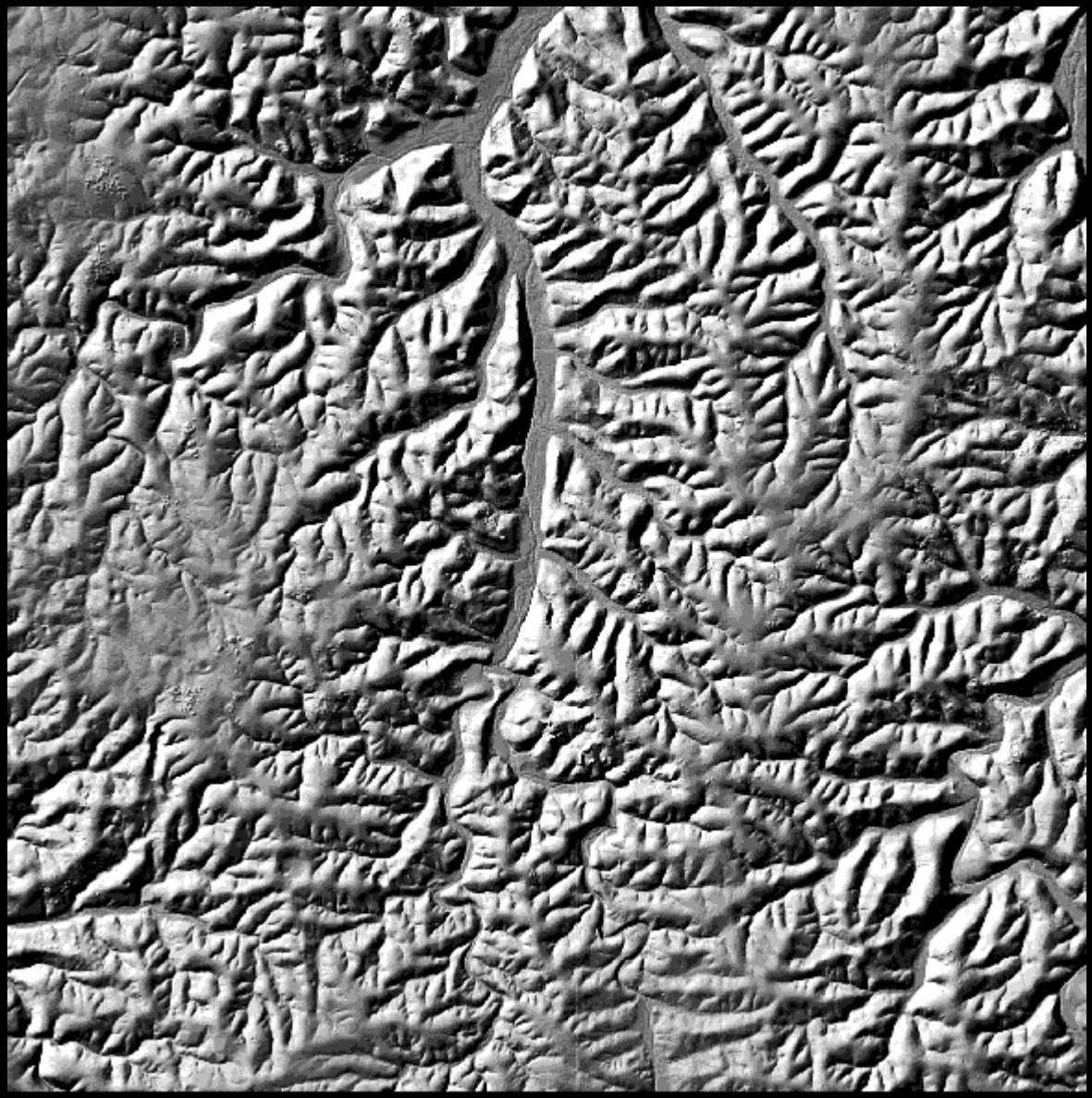


LIDAR DEM – Shaded Relief

LIDAR

10 m spacing

Vertical accuracy < 1m



Produced for USGS by EarthData

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IKONOS DEM – Shaded Relief

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LIDAR DEM – Shaded Relief

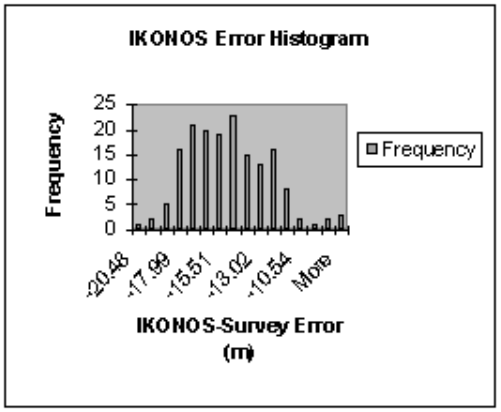
DEM Accuracy

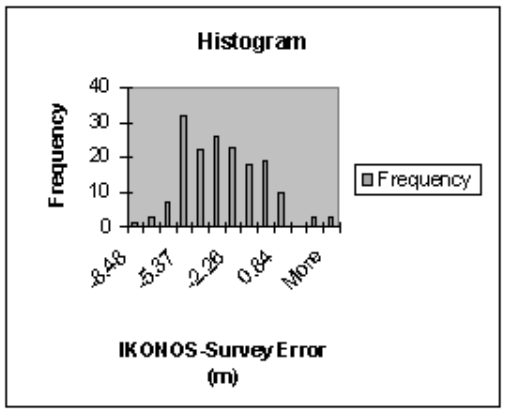
IKONOS DEM TEST RESULTS

IKONOS Lattice Stats (meters)

Original DEM			DEM with +12 m Bias Adjustment		
sum sq	**sum sq/n**	**RMSE**	**sum sq**	**sum sq/n**	**RMSE**
40420.03	242.04	15.56	2900.93	17.37	4.17

Lat-Survey			*"lat-survey"+12m*	
Mean	-15.36	*	Mean	-3.36
Standard Error	0.19		Standard Error	0.19
Median	-15.52		Median	-3.52
Mode	-18.38		Mode	-6.38
Standard Deviation	2.47	*	Standard Deviation	2.47
Sample Variance	6.11		Sample Variance	6.11
Kurtosis	0.12		Kurtosis	0.12
Skewness	0.52		Skewness	0.52
Range	12.43	*	Range	12.43
Minimum	-20.48	*	Minimum	-8.48
Maximum	-8.05	*	Maximum	3.95
Sum	-2565.30		Sum	-561.30
Count	167.00		Count	167.00





DEM Accuracy

DEMs from Four IKONOS Stereo Pairs and Combination

Images	Vertical Error	Status
2001112217124870000010202074 2001112217134000000010202075	-15.0 m	Clear, Old DEM
2001043017022950000011601246 2001 0430170318300000011601247	+2.0 m	Partly Cloudy
2001050816543660000011607780 2001 0508165525700000011607781	+8.5 m	Partly Cloudy
2001040817002200000011616122 2001 0408170113500000011616123	-4.5 m	Partly Cloudy
All of the above	-3.5 m	New DEM

- Production procedures modified to require 2 or more stereo models for DEM production.
- Information provided by Gene Dial, Space Imaging.

+12 Meter Bias Adjustment

IKONOS DEM TEST RESULTS

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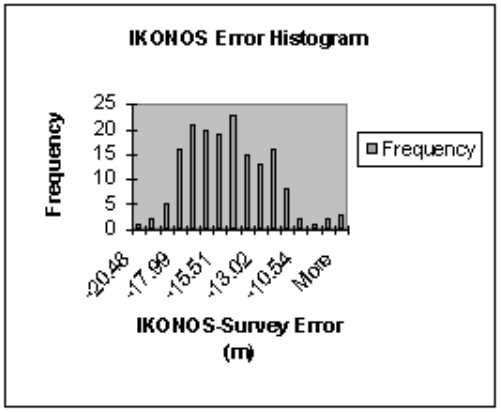
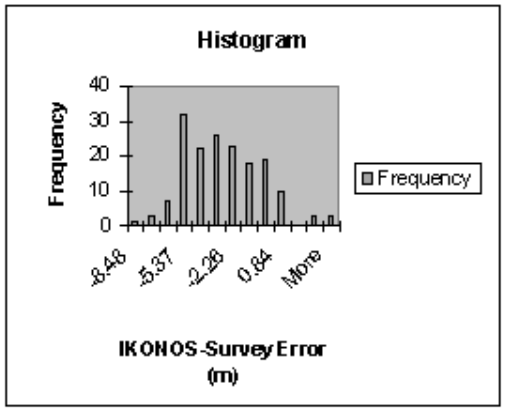


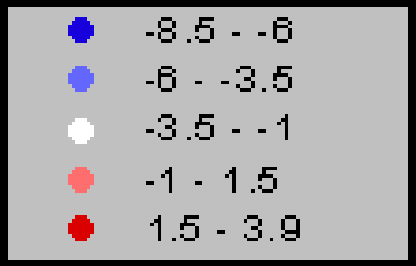


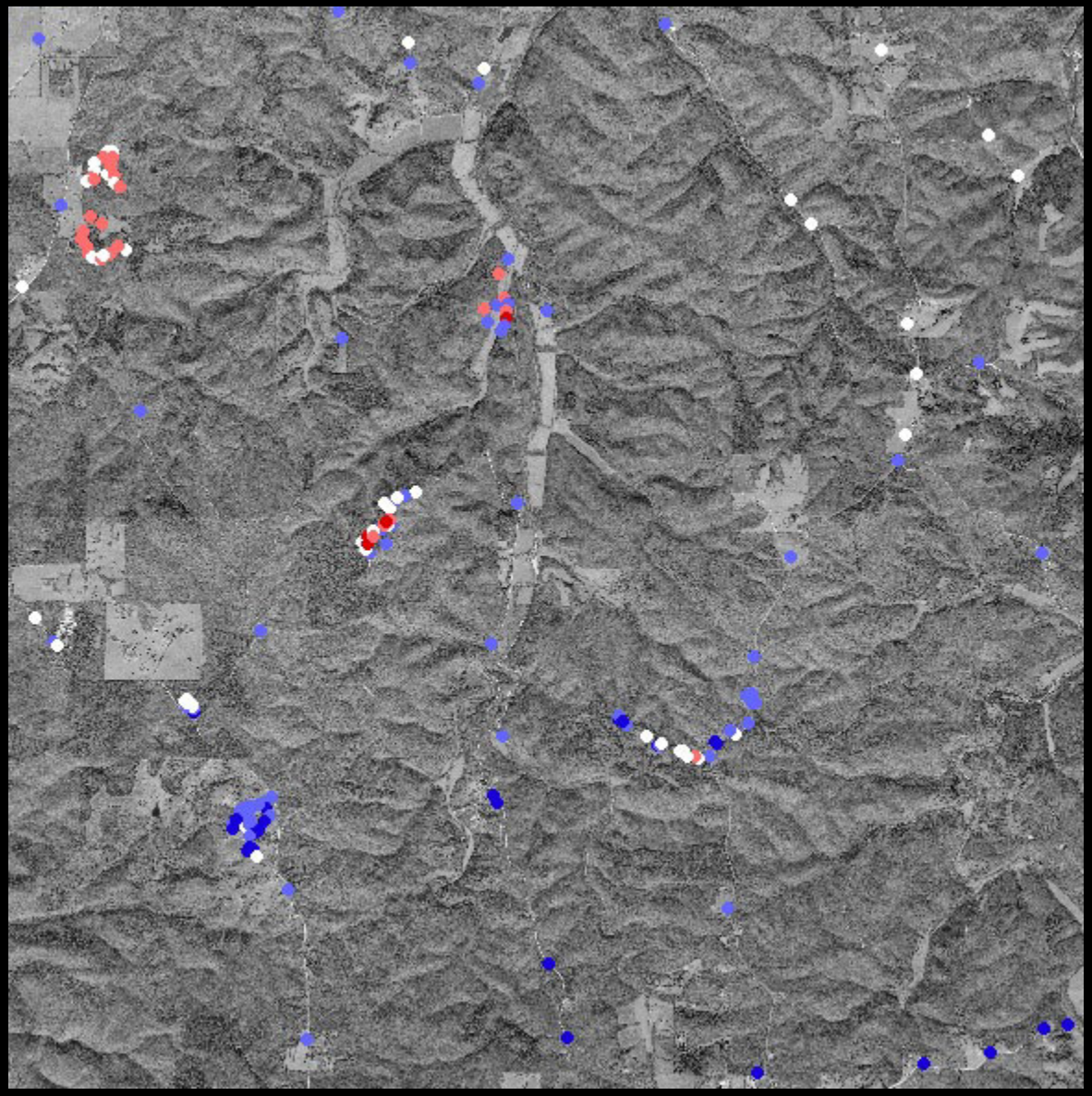
Test Point Errors (after +12m adjustment)

Vertical Error (m)

IKONOS - Survey

167 test points





Comparison:

LIDAR DEM

Adjusted IKONOS DEM

Difference DEM

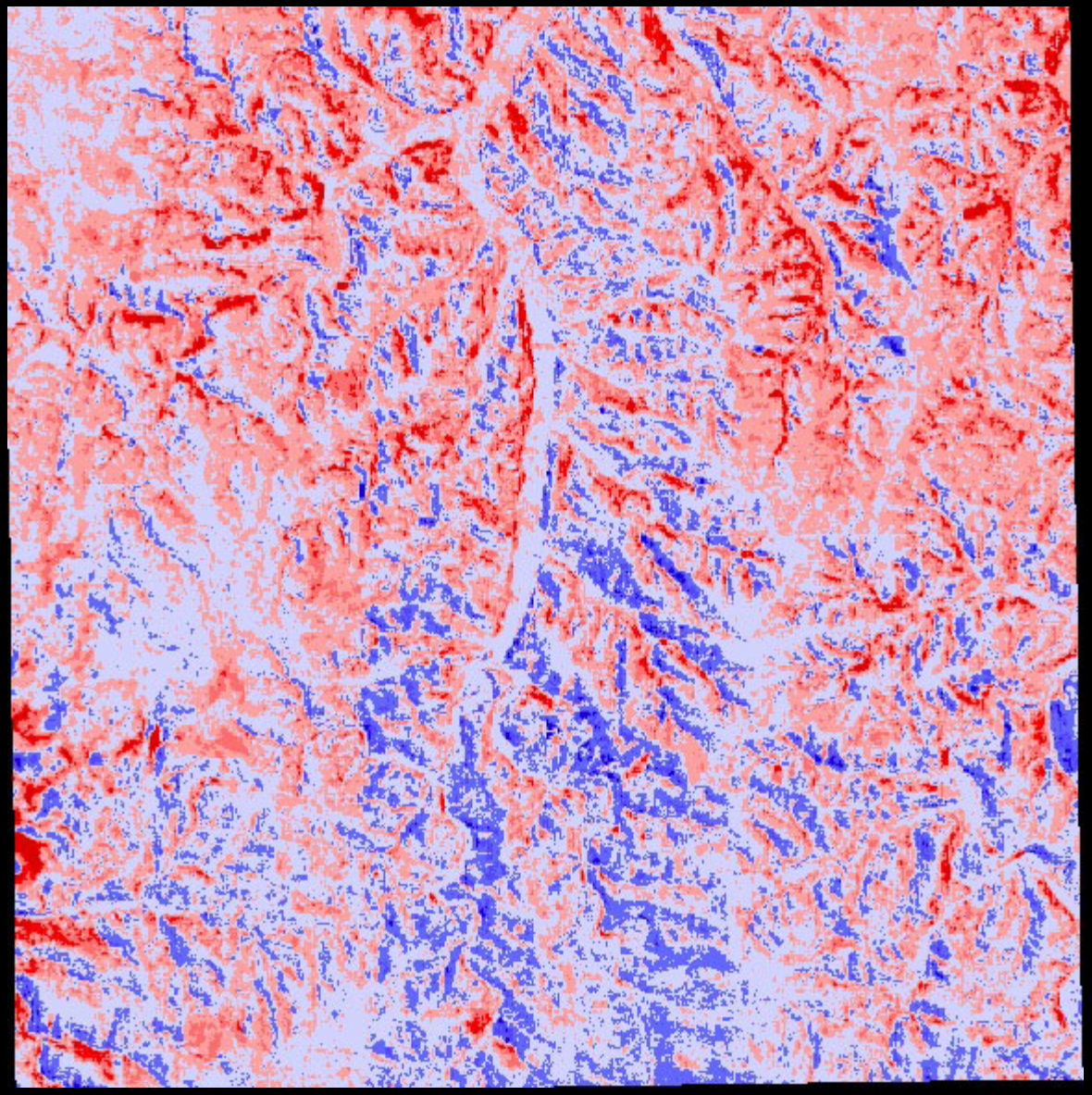
IKONOS open-terrain bias removed

IKONOS (+16.5m) - LIDAR

Blue: IKONOS lower than LIDAR

	-21.3 - -9.8	< -3 Std. Dev.
	-9.8 - -6.2	-3 - -2 Std. Dev.
	-6.2 - -2.7	-2 - -1 Std. Dev.
	-2.7 - 0.9	-1 - 0 Std. Dev.
	0.9	Mean
	0.9 - 4.5	0 - 1 Std. Dev.
	4.5 - 8.1	1 - 2 Std. Dev.
	8.1 - 11.7	2 - 3 Std. Dev.
	11.7 - 27.1	> 3 Std. Dev.
		No Data

Red: IKONOS higher than LIDAR



Difference DEM

IKONOS (adj.) - LIDAR

Blue: IKONOS lower than LIDAR

	-21.3 - -9.8	< -3 Std. Dev.
	-9.8 - -6.2	-3 - -2 Std. Dev.
	-6.2 - -2.7	-2 - -1 Std. Dev.
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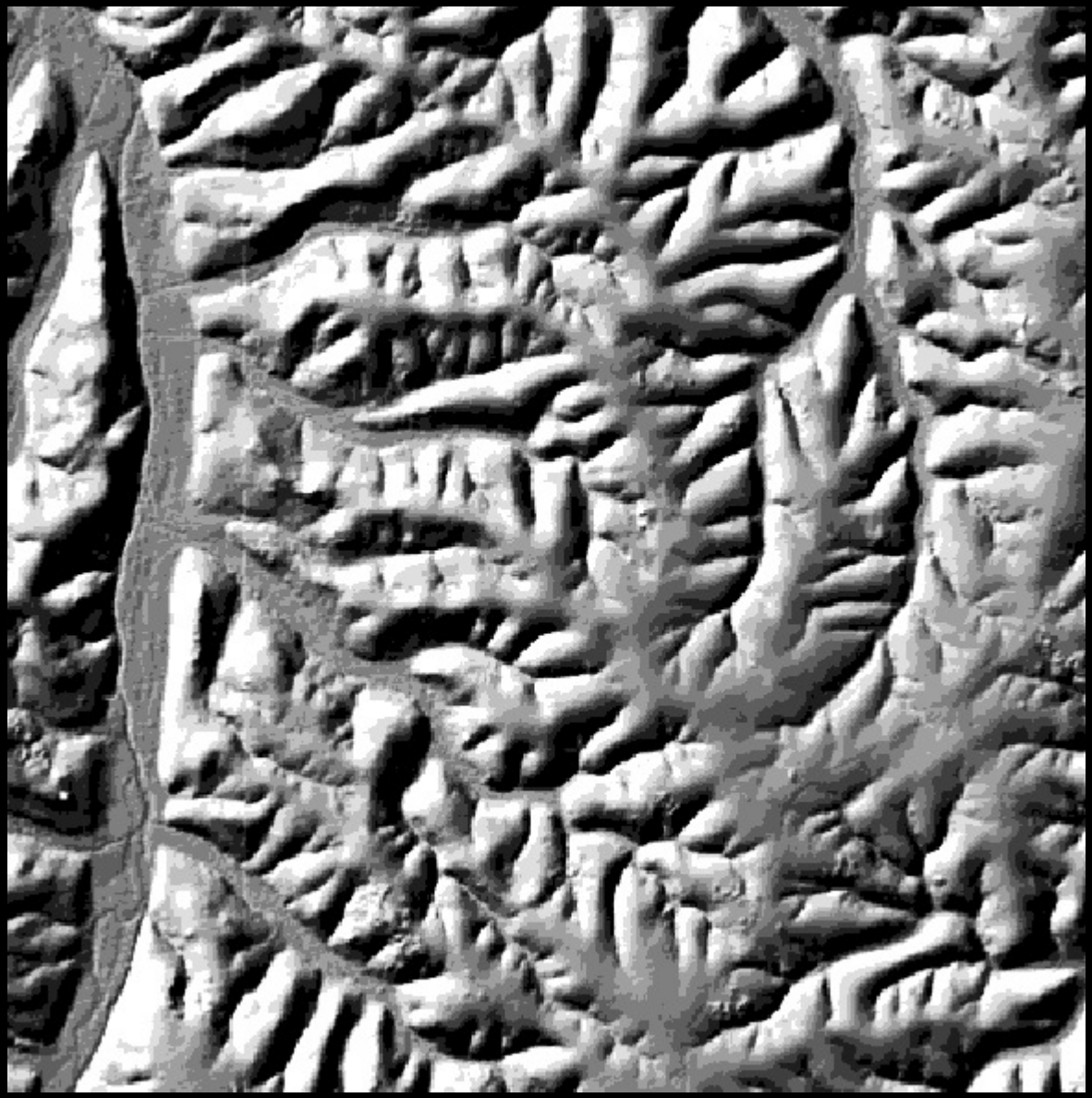
	4.5 - 8.1	1 - 2 Std. Dev.
	8.1 - 11.7	2 - 3 Std. Dev.
	11.7 - 27.1	> 3 Std. Dev.
		No Data

Red: IKONOS higher than LIDAR



Vegetation Effect on IKONOS DEM

Five ground cover types tested:

- Open terrain
- Pasture grass
- Broadleaf forest
- Dense brush
- Pine forest

IKONOS DEM vertical bias of -16.5 m in open terrain.

Vertical Bias removed prior to vegetation analysis.

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Pine Forest

Kaintuck Study Site

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Broadleaf Forest

Brush and Cedar

Kaintuck Study Site

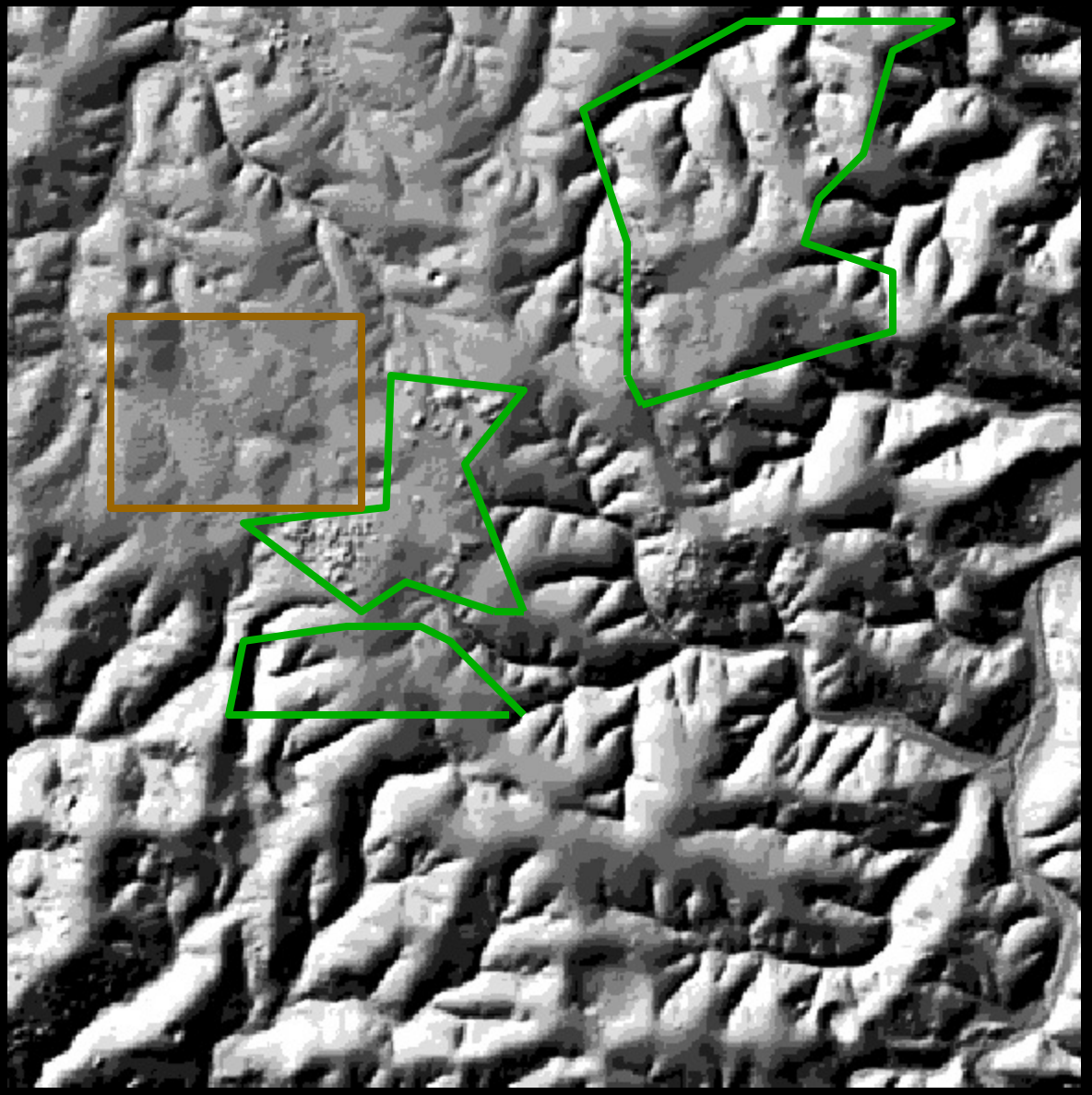
Pasture Grass

Kaintuck Study Site

Vegetation Effect on DEM

Pine forest

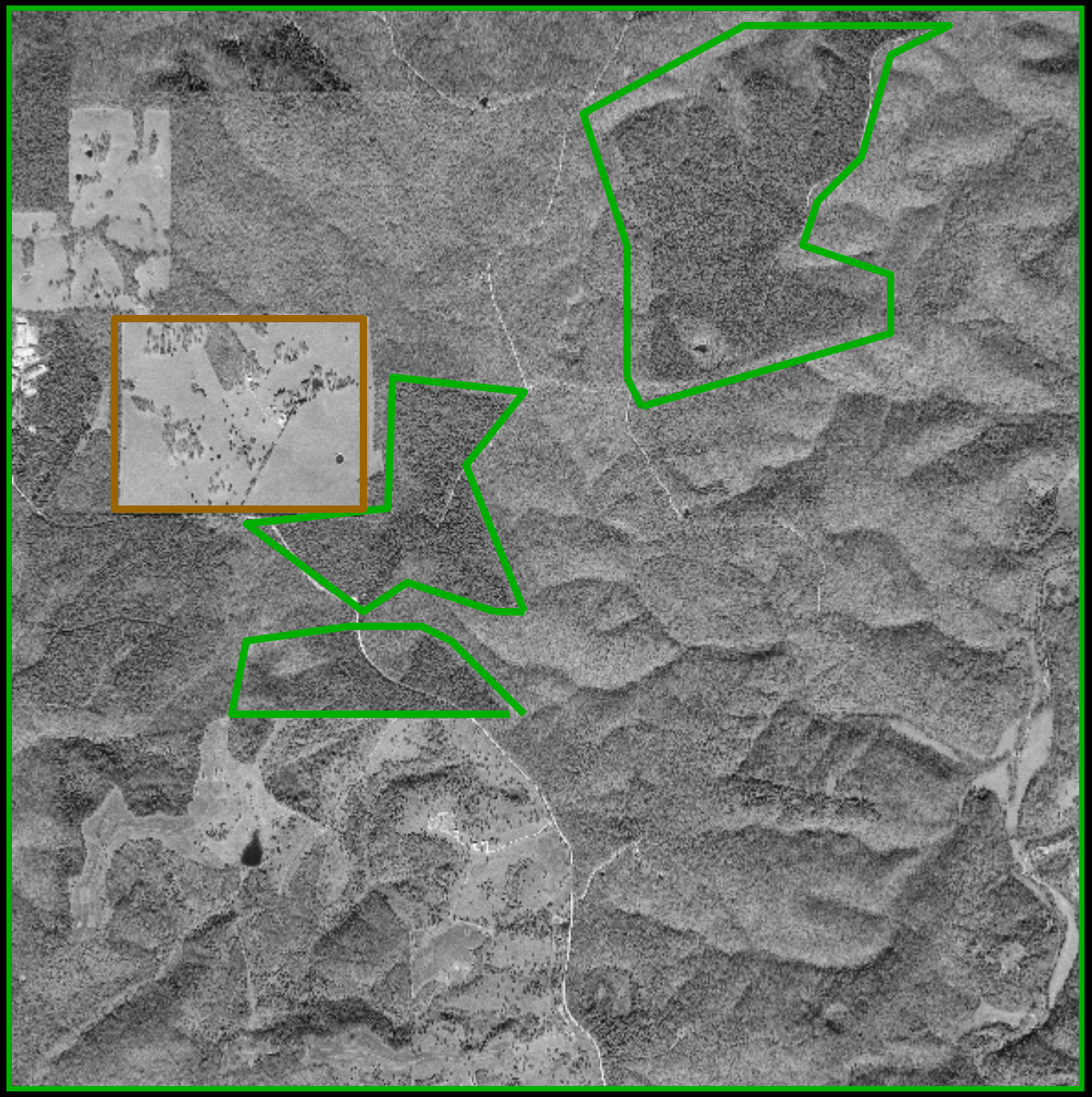
Pasture grass



Vegetation Effect on DEM

Pine forest

Pasture grass



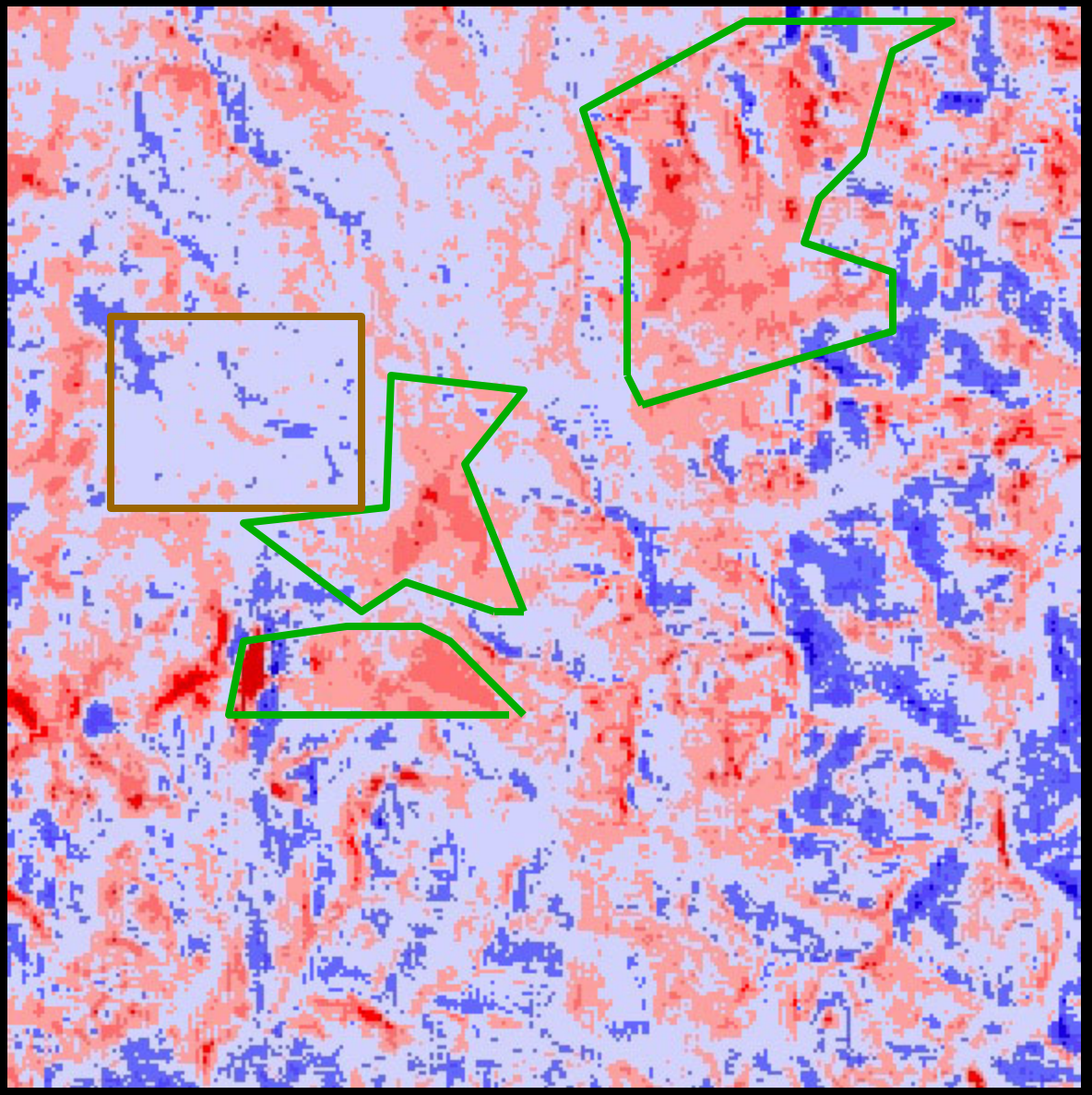
Vegetation Effect on DEM

IKONOS – LIDAR DEM

Pine forest

Pasture grass

	-21.3 - -9.8	< -3 Std. Dev.
	-9.8 - -6.2	-3 - -2 Std. Dev.
	-6.2 - -2.7	-2 - -1 Std. Dev.
	-2.7 - 0.9	-1 - 0 Std. Dev.
	0.9	Mean
	0.9 - 4.5	0 - 1 Std. Dev.
	4.5 - 8.1	1 - 2 Std. Dev.
	8.1 - 11.7	2 - 3 Std. Dev.
	11.7 - 27.1	> 3 Std. Dev.
		No Data



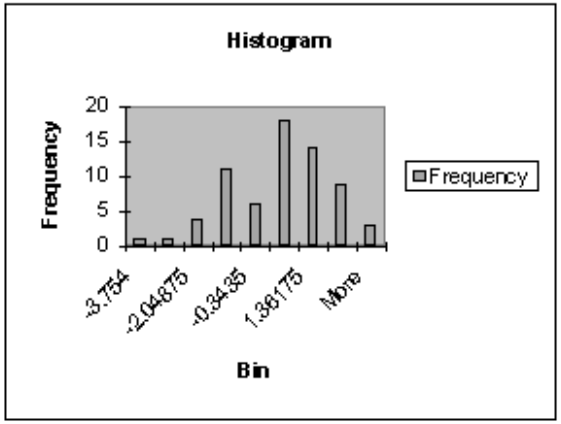
Vegetation Category Stats

After IKONOS DEM Adjustment for Open Terrain Bias

Open Terrain

sum sq	sum sq/n	RMSE	
145.58385	2.172893	1.474074	*

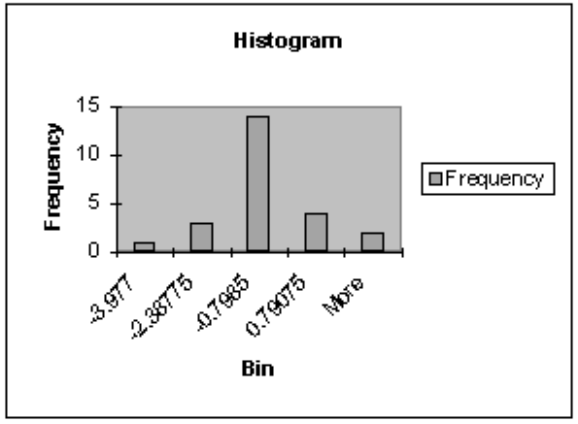
lat-sur +16.5	
Mean	-0.025254
Standard Error	0.181419
Median	0.03
Mode	-1.88
Standard Deviat	1.484981
Sample Varianc	2.205168
Kurtosis	-0.350804
Skewness	-0.140497
Range	6.821
Minimum	-3.754
Maximum	3.067
Sum	-1.692
Count	67



Grass

sum sq	sum sq/n	RMSE	
80.043197	3.335133	1.826235	*

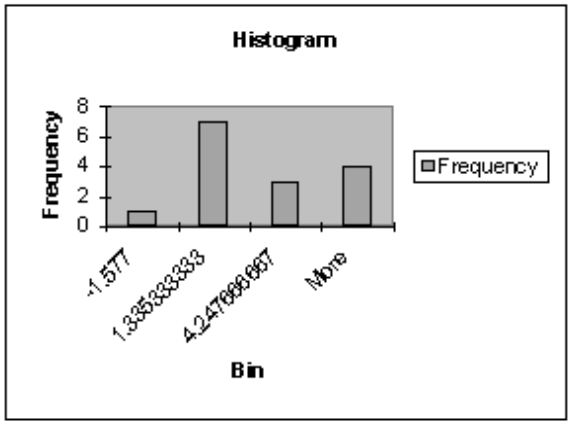
lat-sur +16.5	
Mean	-1.187208
Standard Error	0.289352
Median	-1.26
Mode	#N/A
Standard Deviat	1.417531
Sample Varianc	2.009394
Kurtosis	1.220415
Skewness	0.662723
Range	6.357
Minimum	-3.977
Maximum	2.38
Sum	-28.493
Count	24



Broadleaf

sum sq	sum sq/n	RMSE	
158.807662	10.58718	3.253794	*

lat-sur +16.5	
Mean	1.924533
Standard Error	0.70119
Median	1.01
Mode	#N/A
Standard Deviat	2.715698
Sample Varianc	7.375017
Kurtosis	-1.032979
Skewness	0.410769
Range	8.737
Minimum	-1.577
Maximum	7.16
Sum	28.868
Count	15



Vegetation Category Stats

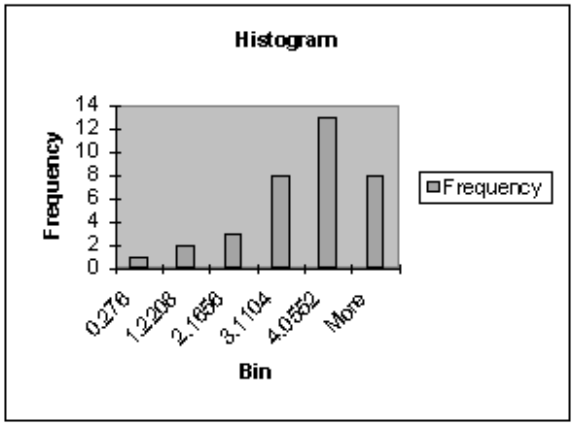
After IKONOS DEM Adjustment for Open Terrain Bias

Dense Brush

sum sq	sum sq/n	RMSE	
398.269991	11.37914	3.373298	*

lat-sur +16.5

Mean	3.163571
Standard Error	0.200804
Median	3.36
Mode	#N/A
Standard Deviat	1.187973
Sample Varianc	1.411281
Kurtosis	0.183939
Skewness	-0.791901
Range	4.724
Minimum	0.276
Maximum	5
Sum	110.725
Count	35

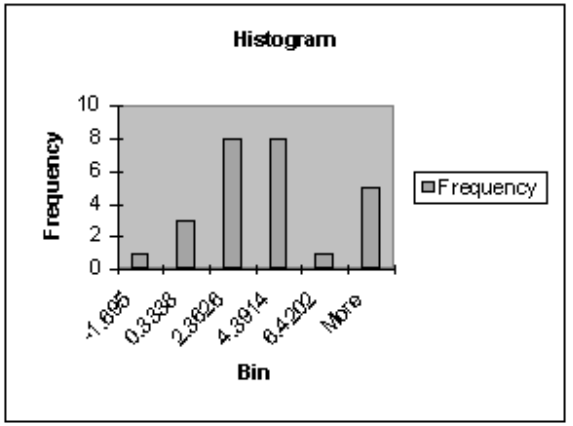


Pine

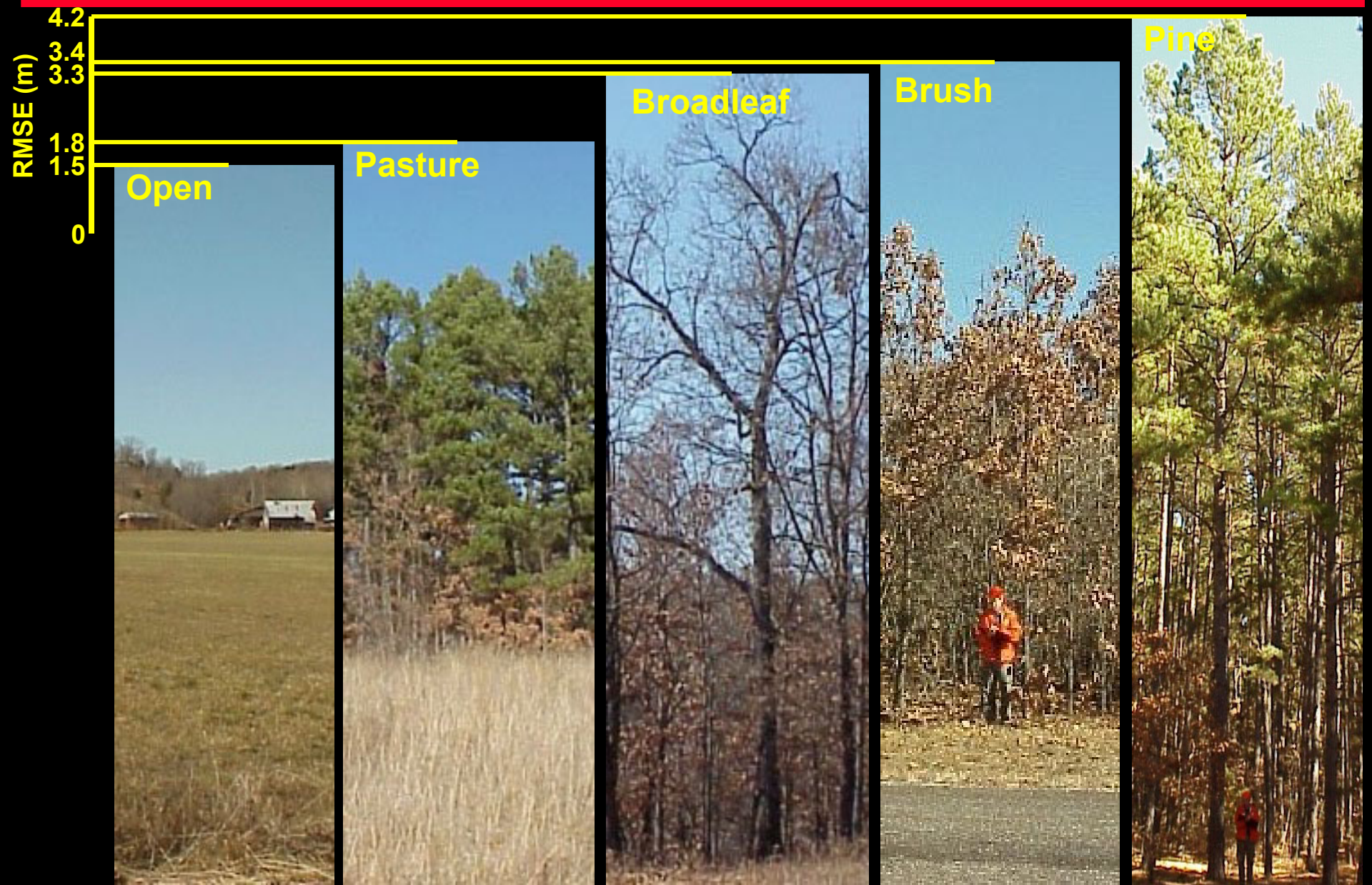
sum sq	sum sq/n	RMSE	
448.312106	17.24277	4.152442	*

lat-sur +16.5

Mean	3.107538
Standard Error	0.550853
Median	2.523
Mode	#N/A
Standard Deviat	2.808811
Sample Varianc	7.889417
Kurtosis	-0.275879
Skewness	0.514508
Range	10.144
Minimum	-1.695
Maximum	8.449
Sum	80.796
Count	26



Vegetation Category Errors



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Conclusions

IKONOS stereo pairs produced DEMs with –15m to +8m vertical error.

A combination of stereo pairs can yield a DEM with less error…

In this case –3.5m.

Analysis of multiple stereo pairs and possible combined solution may be necessary in production process.

Standard deviation of 2.5m is quite reasonable considering the extensive forest cover.

Tall and dense vegetation affect the achievable vertical accuracy.